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INTRODUCTION

This document constitutes the semi-annual report for the NASA-sponsored institutional program in space-related sciences at the University of Florida. The program has been in operation since November 1, 1963, and to date has involved a total of 36 different projects in 10 science and engineering departments of the University. The present report concerns those projects that were active during the period May 1 to November 1, 1965. Descriptions of the work of the individual projects were prepared by the appropriate principal investigators.

It is of interest to note that cf the projects active during the above period, A01, A08, A11 and A12 have been completed, while A20 and A21 have received funding from other sources. Thus funds have been made available for the inclusion of 6 new projects, which became active as of November 1, 1965. It should, perhaps, be pointed out that 8 additional new projects were approved by the University of Florida NASA Steering Committee as highly qualified for support, but funds were not available to activate them.

PROJECT A01

STUDY OF THE 20 MC/SEC SIGNAL FROM THE S-66 SATELLITE

1. Department: Physics and Astronomy

2. Principal Investigator: A. G. Smith

3. Background: For nine years the Department of Physics and Astronomy has been monitoring and analyzing the decameter-wavelength radiation from the planet Jupiter. This program has resulted in nearly 50 publications in books and journals, and a total of 26 graduate theses and dissertations.

In the decameter wavelength range Jovian radio signals are received as bursts of pulses. Normally the pulse duration is of the order of a few tenths of a second but occasionally a far more rapid popping or "spitting" occurs. More rarely, very slow pulses with durations of many seconds are observed. As long ago as 1958 a brief experiment by Gardner and Shain raised a serious question as to the real origin of this pulse structure. Two antennas 25 km apart were used for simultaneous reception of outbursts from Jupiter, and the signals were compared by means of high-speed pen recordings. The records showed clearly that there were important differences in the signals received at the two sites.

Somewhat later, similar but much more extensive observations were made by Smith and Douglas at Yale and by our own group. In the Yale experiments the baseline ranged from 15 to 100 km, while we employed one baseline of 55 km and another of 7040 km. Over the shorter baselines the results were variable; often the two signals were nearly identical, but at other times the pulse-to-pulse correlation was quite poor. For the 7040 km baseline the correlation was essentially zero in all but a few rare instances. At this great distance even the bursts of pulses often failed to coincide in time, so that there was an alternating fading of the signal at the two sites. Since the average period of this fading was of the same order as the scintillation period observed for radio stars (about 30 sec), it seemed reasonable to conclude that much of the burstiness of the Jovian signal was due to irregularities in the local ionosphere. At the same time, this left open the important question of the origin of the individual pulses themselves. It seemed significant that changes in the pulse character from "normal" to "spitting," or vice versa, often occurred almost simultaneously at the two sites over 7000 km apart.

The present study was designed to illuminate the vital problem of pulse origin by comparing Jovian pulse structure with scintillation phenomena known to be ionospheric in origin--in this case signals from radio stars and from the S-66 or BE-B beacon satellite.

4. Progress from May 1 to November 1, 1965: Observations were continued through June, using the equipment described in earlier reports. Mr. W. A. Morton, a master's candidate, and Mr. W. F. Block, a doctoral candidate, continued routine observations of favorable passes of BE-B, and the observations

were also extended to BE-C following the launching of that vehicle. As before, attention was concentrated on the 20 Mc/sec signals, since they lie in the center of the decametric band. Beginning in July, the efforts of the group were concentrated on analysis of the large accumulation of data and the formulation of conclusions. As will be seen in Section 5, several publications were also prepared.

To quantify the investigation, a Jovian "pulse character" scale was evolved in which the character, C, was defined as 1 for "slow" pulses, 2 for "normal" pulses, and 3 for "spitting." A comparable index, S, was defined for the satellite observations; on this scale S = 0 corresponded to no scintillation, while S = 2 represented scintillation so strong that the normal periodic modulation due to Faraday rotation was totally obliterated. Comparisons were also made with the radio star data of Hewish and of Koster and Wright.

In one important study, C, S, and radio star scintillation were plotted as functions of source altitude. As expected, the satellite and radio star scintillation indices increased as the altitude decreased. On the other hand, Jovian pulse character seemed to be independent of altitude. A similar study found the Jovian data lacking the strong diurnal variation displayed by the satellite and radio scintillation. Although the results were less clear-cut, the seasonal variation reported for radio star scintillation appeared to be missing in the Jupiter observations. By far the most direct experiment was that of making simultaneous 20 Mc/sec observations of Jupiter and S-66 when the two were near appulse. The results indicated a total lack of correlation between C and S. Taken in toto, the above comparisons suggest that Jovian pulse character is not determined by the same factors that control the scintillation of satellite and radio star signals. This in turn implies that the local ionosphere is <u>not</u> the source of the basic Jovian pulse.

The foregoing conclusion is consistent with the suggestion of Douglas and Smith that the pulses originate in interplanetary space. This idea is of course related to Hewish's discovery of "interplanetary scintillation" of radio stars of unusually small angular subtense. However, it is interesting to note that our study shows, at least for the one year analyzed, a marked dependence of C on the System III longitude of the Jovian central meridian; the principal effect is a tendency for fast pulses to be observed when the "B" source is on the central meridian. This of course suggests that at least that type of pulse may originate at the planet itself.

It is believed that the present study has answered (negatively) the original question of the relationship between the Jovian pulse structure and scintillation phenomena known to originate in the ionosphere. In so doing it has made a significant contribution to the important problem of the origin and mechanism of the Jovian decametric emission. The project also resulted in the accumulation and analysis of a large quantity of data on the scintillation of satellite signals as a function of altitude, season, time-of-day, look angle, latitude and geomagnetic disturbance. Certain lines of investigation suggested by this project will be pursued under other funding, but since the initial objective has been met, no further support will be requested for Project A01.

5. Publications:

Alex G. Smith, W. F. Block, W. A. Morton, G. R. Lebo, and T. D. Carr. "Influence of the Terrestrial Environment on the Temporal and Statistical Characteristics of Jovian Decametric Radiation." 2nd Symposium on Radio Astronomical and Satellite Studies of the Atmosphere, Cambridge, Massachusetts. October 19-21, 1965. (To be published in Radio Science.)

Alex G. Smith, G. R. Lebo, C. N. Olsson, W. F. Block, N. F. Six and T. D. Carr. "Jovian Rotation Periods and the Origin of the Decametric Burst Structure." Invited contribution presented at the NASA-sponsored CALTECH-JPL Lunar and Planetary Conference, September 13-18, 1965. (To be published in the Proceedings of the Conference.)

W. A. Morton, Ionospheric Scintillation of the 20 Mc/s Signals from the BE-B and BE-C Beacon Satellites, M.S. Thesis, University of Florida, August, 1965.

Alex G. Smith, W. F. Block, G. R. Lebo and T. D. Carr. "Tests for Local Modulation of Jovian Decametric Emission." Southeastern Section of the American Physical Society, University of Virginia. November 1-3, 1965. (Abstract to be published in Bull. Amer. Phys. Soc.)

6. Budget for Period May 1 to November 1, 1965:

Salaries	$ -----
Expense	227.50
Capital Equipment	-----
TOTAL EXPENDITURES	$ 227.50

PROJECT A02

OBSERVATIONS WITH THE ARECIBO 1000-FOOT RADIO TELESCOPE

1. Department: Physics and Astronomy

2. Principal Investigator: T. D. Carr

3. Background: The primary objective of this project is to make systematic observations of the planet Jupiter at 430 Mc/s with the 1000-foot reflector radio telescope in Puerto Rico to obtain information relating to the rotation period and magnetic field of the planet, the synchrotron emission process, the Jovian Van Allen belts, and possible solar influences.

4. Progress from May 1 to November 1, 1965: Mr. Frank Tiberi has continued theoretical investigations to account for the results of his Jupiter observations made in Arecibo during early 1964 and early 1965. A definite variation of radio intensity with respect to System III longitude was found for each of the two series of observations, but the later curve was displaced about 30° toward higher longitudes than the earlier one. Mr. Tiberi believes that a part of this displacement may have resulted from the presence of a previously undetected variable circularly polarized component. His experimental and theoretical results will be presented in his doctoral dissertation, which is nearing completion. Financial support of Mr. Tiberi by the project ended on September 30.

The principal investigator worked at the Arecibo Ionospheric Observatory from August 7 to August 29 and from October 5 to October 30. A plan for future observations of Jupiter with the large radio telescope was submitted to the scheduling committee and was approved. As the first part of this new program, the principal investigator and Dr. Samuel Gulkis of the Cornell staff at Arecibo observed Jupiter during most of October at 430 Mc/s. The purpose of the new observations was to determine whether the abnormally large longitude drift found by Tiberi has persisted, and to obtain a more accurate measurement of the rotation period of Jupiter's magnetic field. Reduction of the data is not yet complete.

The principal investigator has started a design study of a polarimeter feed antenna to be used with the 1000-foot dish to measure the circular components of the radiation from Jupiter at 430 Mc/s.

5. Publications:

Jorge May. Studies of the Radio Noise Bursts from Jupiter, M. S. Thesis, University of Florida, August 1965 (contains results of 6.3 Mc/s Jupiter observations at Arecibo).

Samuel Gulkis. A Theoretical Model for the Emission of the Decametric Radiation from Jupiter, Ph.D. Dissertation, University of Florida, April 1965 (omitted from previous report).

T. D. Carr and C. F. Tiberi. "Observations with the Arecibo 1000-foot Radio Telescope," Annual Meeting of the Southeastern Section, American Physical Society, Charlottesville, Virginia, November 2, 1965. Abstract to be published in Bul. Amer. Phy. Soc.

6. Budget for Period May 1 to November 1, 1965:

Salaries	$ 3,690.00
Expenses	1,290.84
TOTAL EXPENDITURES	$ 4,980.84

PROJECT A03

AN INVESTIGATION OF THE LOW-FREQUENCY EXTREME OF THE JOVIAN RADIO SPECTRUM

1. Department: Physics and Astronomy

2. Principal Investigator: A. G. Smith
Co-investigator: C. N. Olsson

3. Background: As explained in previous reports for this project, studies made at the University of Florida have indicated that a major portion of the Jovian decametric energy probably lies in the extreme low-frequency tail of the spectrum. Both the absolute intensity of the signals and the probability of occurrence increase as one goes toward the lower frequencies. Furthermore, significant changes occur in the apparent structure of the decametric sources at frequencies below 15 Mc/sec. The polarization phenomena furthermore seem to be more significant at the lowest frequencies than in the remainder of the decametric spectrum. For all of these reasons it is evident that any serious attempt to develop an adequate theoretical model of the emission process must rely heavily on data taken at the lowest possible frequencies.

Unfortunately, the region below 15 Mc/sec is one of great experimental difficulty because of both natural and man-made interference as well as the opacity of the terrestrial ionosphere. The present project was designed to investigate the advantages that might be gained by placing the antennas in a site which is not only extremely well shielded, but also as remote as possible from all sources of artificial interference. A field station has been established in a deep mountain valley in the Chilean Andes inland from the coastal city of LaSerena, and observations have been in progress since the summer of 1964. The equipment at this station includes an 8-element 5 Mc/sec interferometer with a baseline of 3,000 feet, an 18 Mc/sec steerable yagi antenna, a 10 Mc/sec broadside array and a 12 Mc/sec polarimeter. The station is manned by Chilean personnel, with the assistance of the University of Chile and occasional visits by University of Florida personnel.

It should be pointed out that this field site is regarded as an important back-up facility for the satellite receiver project that is under development by the radio astronomy group under a separate contract with NASA (NASA-NASR-176). The satellite receiver, which is tentatively planned for an OGO flight, will monitor channels at 0.5, 1.0, 2.0 and 4.0 mc which will tie in extremely well with the 5 mc ground-based data. Since identification of radiation is expected to be the primary problem in the space experiments, this ground back-up data is regarded as being of the utmost importance. At the present time development of a prototype satellite radiometer has been completed and the engineering model is undergoing tests at the University of Florida.

4. Progress during the period May 1 to November 1, 1965: A one year's accumulation of data has now been returned from the Huanta station to the University of Florida and analyzed. One of the first results to come out of this analysis has been the demonstration of an unexpectedly high site influence on the 18 Mc/sec data. Although the 18 Mc/sec listening conditions appear to

be excellent most of the time at the Florida station and at the original Chilean site near Santiago, the probability of receiving emission at the Huanta site is almost exactly double that at either of the other sites. During the optimum two months of the 1964-1965 apparition of Jupiter, the probability of receiving radiation from the principal source ("A") reached the unprecedentedly high value of 0.8. For the same period the probability of reception from this same source at the Florida site and at the Santiago site was 0.4. Similarly, when the results were averaged over the entire apparition, the source "A" probability for the Huanta site was 0.5. and for the Florida and Santiago sites it was only 0.25. Thus the factor of 2 seems to be essentially independent of the time periods that are compared. This unexpectedly large factor substantiates previous suspicions of the importance of the role of the site in decametric observations even at frequencies as high as 18 Mc/sec.

During the summer of 1965 Professor C. N. Olsson and Dr. W. F. Block of the University of Florida each spent approximately two months at the Huanta station improving the instrumentation and supervising the taking of data. The station suffered some damage to antennas during the wind storms which marked the unusually violent Chilean winter of 1965. However, this damage was quickly repaired and all channels are currently making observations. Intensive monitoring of Saturn is also being continued in an effort to determine whether that planent is a decametric emitter. As noted in Section 5, several papers have now been prepared and presented including the results of the observations at the Huanta station.

5. Publications:

G. R. Lebo, A. G. Smith and T. D. Carr. "Correlation of the Longitudes of the Galilean Satellites with Jupiter's Decametric Radiation." American Astronomical Society, Lexington, Kentucky, March 14-17, 1965. (Abstract published in Astron. Journal. 70, 325.)

Alex G. Smith, G. R. Lebo, C. N. Olsson, W. F. Block, N. F. Six and T. D. Carr. "Jovian Rotation Periods and the Origin of the Decametric Burst Structure." Invited contribution presented at the NASA-sponsored CALTECH-JPL Lunar and Planetary Conference. September 13-18, 1965. (To be published in full in the Proceedings of the Conference.)

Alex G. Smith, W. F. Block, W. A. Morton, G. R. Lebo and T. D. Carr. "Influence of the Terrestrial Environment on the Temporal and Statistical Characteristics of Jovian Decametric Radiation." 2nd Smyposium on Radio Astronomical and Satellite Studies of the Atmosphere, Cambridge, Massachusetts, October 19-21, 1965. (To be published in full in Radio Science.)

G. R. Lebo, T. A. Anderson and A. G. Smith. "The Effect of Io on Jovian Decametric Radio Emission." Southeastern Section of the American Physical Society, University of Virginia. November 1-3, 1965. (Abstract to be published in the Bull. Amer. Phys. Soc.)

C. N. Olsson, Alex G. Smith and G. R. Lebo. "Jovian Rotation Periods." Southeastern Section of the American Physical Society, University of Virginia. November 1-3, 1965. (Abstract to be published in the Bull. Amer. Phys. Soc.)

6. Budget for Period from May 1 to November 1, 1965:

Salaries	$ 7,913.32
Expenses	6,326.28
Capital Equipment	-0-
TOTAL EXPENDITURES	$14,239.60

PROJECT A05

NUCLEAR ASTROPHYSICS

1. Department: Physics and Astronomy

2. Principal Investigator: F. E. Dunnam

3. Background: The primary purpose of these investigations is to measure nuclear reaction parameters which are needed in order to predict accurately the nature of the nuclear processes taking place in stellar interiors. In many cases, quantities such as the reaction cross-sections must be known before one can decide which of two competing reactions will take place. If the process in question occurs early in the life of the star, it will obviously have great influence on the subsequent chain of nuclear reactions. Our original proposal was to use the techniques of nuclear physics to measure such parameters as (1) neutron radiative capture cross-sections and (2) cross-sections for production of light nuclei by proton bombardment of various elements with the beam from a Van de Graaff accelerator.

4. Progress from May 1 to November 1, 1965: Two factors, namely the lack of good neutron shielding in our experimental area and the ready availability of a helium-4 beam from our accelerator, have resulted in our augmenting the above program with some studies of alpha-capture reactions. The importance of this process in stellar element creation is well known. In particular, we are investigating the structure of several so-called "even-even" nuclei (e.g. $_{14}Si^{28}$, $_{16}S^{32}$, $_{18}A^{36}$) produced by helium-4 bombardment of an appropriate target. Apparatus constructed by our group and mentioned in earlier reports enables us to (1) produce thin targets by evaporation of practically any desired material, (2) to count and determine energies of gamma rays produced in any radiative capture reactions, and (3) to measure the angular distribution of these gamma rays, thus determining the spin and parity of any excited nuclear states. W. A. Bruton, M. M. Swisdak and P. N. Carlton have been studying excited states of Si^{28} and S^{32}; they appear to have discovered two hitherto unknown resonances in S^{32} at alpha energies of 3.315 and 3.370 MeV, respectively. Our work to date indicates that these levels do not decay to the ground state in a single transition , so that accurate determination of the spin and parity of these levels awaits angular correlation measurements, which we intend to perform shortly. Beyond Si^{28}, no one else appears to have made studies of this type for alpha energies of 3.2 to 4 MeV; we therefore plan to explore this energy range thoroughly during the coming year.

5. Publications:

William Allen Bruton, A Study of Some Excited States of the Si^{28} Nucleus. M.S. Thesis, University of Florida, August 1965.

6. Budget for Period May 1 to November 1, 1965:

Salaries	$ 9,130.00
Expenses	3,960.56
Capital Equipment	5,791.00
TOTAL EXPENDITURES	$18,881.56

PROJECT A06

MAGNETOFLUIDMECHANICS

1. Departments: Aerospace Engineering and Electrical Engineering

2. Principal Investigators: M. H. Clarkson and B. E. Mathews

3. Background: The initial purpose of this project was to develop diagnostic techniques for rf-generated plasmas. Work has continued in this direction, but emphasis is gradually shifting toward the use of these diagnostic techniques in obtaining a better understanding of the nature and characteristics of electrodeless discharges.

4. Progress from May 1 to November 1, 1965: Currently, there are two Ph.D. and three M.S. candidates from Aerospace Engineering, and two Ph.D. and one M.S. candidates from Electrical Engineering working on the project. A brief review of the various studies in progress follows:

(a) Probe Studies. A modification of the asymmetric triple probe technique described by Okudo and Yamamoto (Journal of Applied Physics, Vol. 31, No. 1, January, 1960, p. 158-162) has been applied to electrodeless discharges. The results of this work are to be presented at a conference on plasmadynamics in March. (See 5^b below.)

A magnetic field probe has been constructed, calibrated, and successfully used to measure the fields produced by the excitation coils without a plasma. Tests are now under way to use this method in the desired plasma environment. Results thus far look hopeful. This study is the topic for a master's thesis.

A study of an electric field sensor consisting of a small incandescent bulb, a fiber optic transmission line, and a photo-detector has been completed. At present, this method is not applicable in a plasma environment, but it can be used to detect the effect of the plasma on the electric field external to the container. This study is reported in the master's thesis 5^d listed below.

A radiofrequency mass spectrometer was designed, built and used to determine the positive ion species detectable in various plasmas. In argon, only Ar^+ was found. In nitrogen N_2^+ and N^+ were found in approximately a 10 to 1 ratio. In helium, He^+ and O^+ were found in equal abundance. O_2^+ and H^+ were also detected, but with an abundance about half of the above. Gases were those commercially available, and purging of the system before introducing each gas was done simply by pumping the system down to about 10^{-5} torr and keeping it at this level for about 24 hours. The details of this work are reported in 5^e.

(b) Analysis. The experimental set-up for the plasma loaded wave guide has been completed, and standing wave patterns have been successfully detected as discussed in the last report. However, since the plasma is nonhomogeneous, with large axial variations within distances comparable with a wavelength, the mathematical relationship between the standing wave pattern and the plasma characteristics (electron number density and collision frequency) is not easy

to obtain. This study leads one into the general area of propogation in nonhomogeneous plasmas. This program is a dissertation topic for a doctoral student who has been conducting an analytical study for the last few months. The study combines diagnostic techniques with propagation through media with spatial variations in electron number density.

A second area of analysis involves the solution of Maxwell's equations with boundary conditions corresponding to the electrodeless discharge. This has been done for the case of conductivity decreasing parabolically from a maximum at the center to zero at the wall. It was found that phase differences between the wall and the center depend on the average number density. This shows promise of becoming a useful diagnostic technique, and is the subject of a master's thesis now in preparation.

5. Publications:

(a) M. Clarkson, R. Field, and D. Keefer, "Electron Temperatures in Several RF-Generated Plasmas." Accepted for publication by the Journal of the AIAA.

(b) D. Keefer, M. Clarkson, and B. Mathews, "Probe Measurements in an Electrodeless Discharge." To be presented at the AIAA Plasmadynamics Conference to be held at the U. S. Navy Postgraduate School, Monterey, California, March 2-4, 1966.

(c) Roswell Edward Lee, Jr., Symmetrical Double Probe Measurement of an Induction Coupled RF Plasma, Master's Thesis, University of Florida, June, 1965.

(d) Duane Ernest Bowyer, A Method for Measuring Radio-Frequency Electric Fields in a Plasma, Master's Thesis, University of Florida, August, 1965.

(e) Joseph Orley Lung, A Radio-Frequency Probe for the Mass Analysis of a Plasma, Master's Thesis, University of Florida, December, 1965.

6. Budget for Period of May 1 to November 1, 1965:

Salaries	$ 41,723.00
Expenses	2,852.00
Capital Equipment	5,025.00
TOTAL EXPENDITURES	$ 49,600.00

PROJECT A08

BEHAVIOR OF INFLATABLE STRUCTURES

1. Department: Engineering Science and Mechanics

2. Principal Investigators: W. A. Nash and F. H. Ho

3. Background: Briefly, the objectives of the study have been to present a new and unique theory for finite-nonlinear deformations of initially flat inflatable plates as well as inflatable shallow shells. It was desired to include a consideration of thermal effects, as well as presenting an order-of-magnitude analysis to determine which of the many terms of the equations are the significant ones. Lastly, it was desired to solve these new governing equations for several cases of practical interest, including free vibrations of inflatable shallow shells.

4. Progress from May 1 to November 1, 1965: During the six months preceding 1 November 1965, a nonlinear large deflection theory for an airmat shallow shell was derived by the use of the principle of minimum potential energy. It was assumed that the facings were orthotropic membranes, and further that the faces were geometrically and inelastically identical. The thickness of the shell, however, was regarded as a variable. Further, it was assumed that the drop cords connecting the facings were evenly spaced and that they were straight before and after deformation. Lastly, the internal pressure was taken to be constant with respect to the spatial variables describing the middle surface of the system. Further, it was assumed that all of the material in the system remained perfectly elastic and that the change of intensity of internal pressure due to temperature change was negligible. An application of the principle of minimum potential energy, together with an order-of-magnitude analysis to systematically discard significant higher order terms, leads to the following group of five equations governing the motion of the inflatable shallow shell:

$$N_{11,x} + N_{12,y} - ph_{,x} = -\tilde{B}_1 + \tilde{\rho}\ddot{\zeta} \qquad (1)$$

$$N_{12,x} + N_{22,y} - ph_{,y} = -\tilde{B}_2 + \tilde{\rho}\ddot{\zeta}_2 \qquad (2)$$

$$N_{11}(z_{,xx} - \zeta_{2,xx}) + 2N_{12}(z_{,xy} - \zeta_{3,xy}) + N_{22}(z_{,yy} - z_{3,yy})$$

$$- \zeta_{3,x}(N_{11,x} + N_{12,y}) - \zeta_{3,y}(N_{12,x} + N_{22,y})$$

$$+ \frac{1}{h}\left[h_{,xx} M_{11} + 2h_{,xy} M_{12} + h_{,yy} M_{22}\right]$$

$$- p\left[(h\theta_1)_{,x} + (h\theta_2)_{,y}\right] - ph(z_{,xx} + z_{,yy})$$

$$- q_3 + \tilde{\rho}\,\ddot{\zeta}_3 = \tilde{B}_3 \qquad (3)$$

$$M_{11,x} + M_{12,y} - \frac{1}{h}(h_{,x} M_{11} + h_{,y} M_{12})$$

$$- ph(\theta_1 + \zeta_{3,x}) = \frac{h^2}{4}\tilde{\rho}_f\,\ddot{\theta}_1 \qquad (4)$$

$$M_{12,x} + M_{22,y} - \frac{1}{h}(h_{,x} M_{12} + h_{,y} M_{22})$$

$$- ph(\theta_2 + \zeta_{3,y}) = \frac{h^2}{4}\tilde{\rho}_f\,\ddot{\theta}_2 \qquad (5)$$

In the above equations the symbols N represent membrane forces per unit length of the upper and lower face membranes; x, y, z are the rectangular Cartesian coordinates of the system, with the origin of the z-axis being at the middle surface of the composite system; the quantities designated by $\tilde{B}_2$ and $\tilde{B}_3$ may be regarded as reduced body force components, defined as linear combinations of the body forces per unit volume of the face membrane and core multiplied by various linear functions of the thickness of the facing and core; ρ_c denotes the mass per unit volume of the core and ρ_f represents the mass per unit volume of the face membranes (these may be combined in a linear combination with the core and face thicknesses to define a reduced mass density designated as ρ in the above equations).

Also, $Z(x,y)$ represents the equation of the middle surface of the shell and ζ is the mean displacement of the upper and lower face. The components of the moment vector of any composite system are defined by M, the internal pressure by p, while q_i represents the surface loading per unit area of the upper or lower face membranes. The displacement components in the principal directions at a point in the middle of the core and on the lower and upper face layers, respectively, are denoted by u with superscripts 0, 1, 2. The quantity $\frac{}{}$ appearing in the above equations denotes a linear combination of these quantities. The minimum energy principle also yields equations for governing boundary conditions, but they are omitted here for the sake of brevity. Thus, the newly-derived system of nonlinear equations presents significant nonlinear terms describing finite displacements of inflatable shallow shells. Obviously, since general coordinates are employed, the above system applies to a shallow shell of any geometry. An interesting variation of the above equations can be obtained by introducing a stress function when the longitudinal inertial effects are neglected, in which case the five equations may be reduced to a system of four. In the case of a constant-thickness structure, the four final equations can be reduced to a system of three equations. Since the definition of the displacement components employed in this study is different from that used by McComb, the above equations do not reduce to his.

5. Publications:

F. H. Ho and W. A. Nash. "A Large Deflection Theory of Inflatable Shallow Shells," to be submitted for publication in the Journal of the AIAA.

F. H. Ho and W. A. Nash, "Nonlinear Free Transverse Vibrations of Inflatable Shallow Shells," to be submitted for publication in the Journal of the AIAA.

6. Budget for period May 1 to November 1, 1965:

Salaries	$ 8,006.41
Expense	870.96
Capital Equipment	2,123.50
TOTAL EXPENDITURES	$11,000.87

PROJECT A09

FLUID FLOW IN LOW GRAVITATIONAL FIELDS

1. Department: Engineering Science and Mechanics

2. Principal Investigators: J. Siekmann and L. M. Habip

3. Background: The purpose of this investigation is the determination of the dynamic response of a liquid propellant-ullage-elastic container system, subjected to various steady as well as transient maneuvers of the space carrier following a given period of effective weightlessness. The objectives are to determine:

(a) The relative equilibrium configuration and stability of a rotating finite fluid mass under capillary forces, only, at the axis of another rotating fluid, including the effect of electric fields

(b) The dynamic response of a wetting liquid enclosed in a rotating tank in a zero-g environment and subjected to various disturbing forces

(c) The hydroelastic solution for the sloshing of a liquid with a curved free surface in a cylindrical tank having a flexible bottom.

4. Progress from May 1 to November 1, 1965:

(a) Employing essentially the rate of spin of the liquid and the strength of the electric field as parameters, an analytic solution of the problem has been found for a certain relation between these parameters. Numerical computations have been outlined and a physical interpretation of the results has been attempted.

A study of the general case is presently under investigation. A preliminary analysis indicates that the governing differential equation of the problem can be transformed into an equation which has the structure of the so-called "radial wave equation" of quantum mechanics. The well-established methods of this branch of mathematical physics are applied to obtain an approximate solution. The asymptotic solution for large values of the independent variable has been studied, as well as the behavior of the solution for small values of the independent variable.

(b) A complete set of the perturbation equations for the motion of an inviscid and incompressible fluid has been derived and is presently being applied to the problem. A detailed analysis revealed that lengthy and cumbersome calculations are to be expected even for the simple case of a small, steady, transverse, disturbing force of constant magnitude.

(c) An approximate solution has been achieved for the case in which the flexible bottom of the vessel, which is assumed to be a circular cylindrical tank, consists of a clamped thin elastic plate of constant thickness. Mathematical difficulties in fulfilling boundary conditions of the linearized

problem at the bottom suggested that the plate equation be solved approximately. Possibilities to remove the above difficulties are under investigation.

5. Publications: A review of the immense literature related to fluid mechanics in low gravitational environments has been almost completed and will soon be submitted for publication. Further, a manuscript dealing with results of research related to part (a) is presently in preparation and will be submitted for publication early next year.

6. Budget for period of May 1 to November 1, 1965:

Salaries	$ 815.94
Expense	4.80
Capital Equipment	13.20
TOTAL EXPENDITURES	$ 833.94

PROJECT A10

STUDY OF GRAIN BOUNDARY STRENGTHENING IN SOLID SOLUTIONS AS A FUNCTION OF SOLUTE CONCENTRATION AND TEMPERATURE

1. Department: Metallurgical and Materials Engineering

2. Principal Investigator: F. N. Rhines

3. Background: The present investigators have developed a procedure whereby it is possible to separate grain boundary and matrix hardening characteristics in recrystallized alpha brass. This is accomplished at a given composition by measuring macrohardness over a wide range of grain sizes. Hardness is then plotted as a function of grain boundary area, with the intercept at zero area representing the hardness of a brass single crystal averaged over all orientations. The fundamental hardness of the crystal may be subtracted from the total hardness of the polycrystal to obtain the hardness contribution of the grain boundary.

A. Grain boundary hardening in alpha brass at room temperature: The contribution of the grain boundary to hardening was found to be a linear function of grain boundary area for the complete alpha brass series (95-65 w/o copper). The slope of the hardness versus grain size relationship changes with composition, showing a maximum at approximately 70 w/o copper.

B. Matrix hardness in alpha brass at room temperature: The matrix hardness, i.e., hardness at zero grain boundary area, was obtained by extrapolation of the hardness versus grain size curve for each alloy. This hardness shows very little change with composition. The observation that the single crystal hardness does not change appreciably over such a wide range of composition is quite unexpected; it does not seem to conform with normal solid solution behavior.

4. Progress from May 1 to November 1, 1965:

A. Grain boundary and matrix hardening in alpha brass as a function of temperature: The investigation of grain boundary hardening as a function of grain size was extended to three temperatures other than room temperature, these being 77, 573 and 873°K. Hardness increase is directly proportional to decreasing grain size at all temperatures investigated. The matrix hardness decreases almost regularly as a function of rising temperature. This is true also of the grain boundary contribution to hardening. The maximum in grain boundary hardening at 70 w/o copper became less pronounced at 573°K and disappeared completely at 873°K.

B. Relative grain boundary energies:

1. Mercury embrittlement along grain boundaries in recrystallized alpha brass: The penetration of mercury into the grain boundaries of brass is found to maximize at approximately 70 w/o copper. This measurement was made by immersing alpha brass specimens in liquid mercury at approximately 473°K for 48 hours. At this temperature there is correspondence between grain boundary hardening and mercury penetration. Since mercury penetration is believed to be a measure of grain boundary energy, it is suggested that grain boundary hardness is also a function of the energy.

2. Dihedral angles of lead in recrystallized alpha brass: In another attempt to measure the relative grain boundary energy, seven specimens spanning the alpha brass alloys were prepared by adding 3 w/o lead to each composition. After recrystallization the dihedral angles formed by the intersection of grain boundaries with particles of what had been molten lead were measured. The last heat treatment prior to sectioning was approximately 673°K, therefore the resulting analysis is indicative of this temperature. Since this investigation is incomplete, no conclusions will be included in this report.

C. Replication of grain boundaries: Electron microscopy replicas were taken of random grain boundaries on each specimen. Magnifications varied from 5,000x through 30,000x. An analysis of these pictures is in progress.

D. Grain boundary hardening in pure copper: Recrystallized specimens of various grain sizes are now prepared for average grain diameter measurements. These specimens will ultimately be tested following the same procedure as with the alpha brass series. This will add needed information by extending the range of investigation to include pure copper.

5. Budget for period May 1 to November 1, 1965:

Salaries	$3,107.25
Expenses	538.10
Capital Equipment	350.00
TOTAL EXPENDITURES	$3,995.35

PROJECT A11

MECHANISM OF FRACTURE IN HAFNIUM-ZIRCONIUM ALLOYS

1. Department: Metallurgical and Materials Engineering

2. Principal Investigator: Robert E. Reed-Hill

3. Background: The objective of this project was to investigate the influence of oxygen on the plastic deformation of zirconium. Such an investigation was expected to contribute significantly to an understanding of the events leading to fracture in alloys embrittled by oxygen. The zirconium-oxygen system was chosen for study because relatively little work has been done on interstitial solid solutions based on parent metals of the hexagonal close-packed crystal structure. The solid solubility limit of oxygen in zirconium is 29 atomic percent in the temperature range of interest, yet an early investigator of this system noted that only a few at. pct. oxygen suppressed twinning and induced brittleness in his alloys. Considerable work has been done at this laboratory on the role of twinning in the plastic deformation of zirconium, hence the interest in the apparent alteration of twinning behavior by small amounts of interstitially dissolved oxygen.

4. Progress from May 1 to November 1, 1965: Coarse-grained tensile specimens have been prepared from high purity zirconium plate. The zirconium was first machined to the test specimen configuration, then oxidized in pure oxygen at 600°C and finally solution heat treated for 100 hours at 900°C at 10^{-7} mm Hg pressure. The resultant compositions were determined by X-ray diffraction measurements of the lattice parameters of the alloys. The alloys ranged from 0 to 4.18 atomic percent oxygen. The gage sections of the tensile specimens were chemically polished prior to testing.

Tensile specimens of six different oxygen concentrations were tested at five different temperatures: 77°K in liquid nitrogen; 193°K in a dry ice-acetone mixture; 300°K in air; 373°K in mineral oil; and 500°K in vacuum. These tests were conducted at a strain rate of approximately 3.3×10^{-5}/sec. After the yield point had been passed and straining had been allowed to proceed to approximately 0.5% plastic strain, the strain rate was suddenly increased to 3.3×10^{-4}/sec. to obtain the effect of strain rate on flow stress.

The yield point measurements (0.2% offset) revealed a strong temperature dependence, which increased with oxygen content. Thus, for coarse grained zirconium to which no oxygen has been added, the yield stress varied from 14,000 psi at 77°K to 7,000 psi at room temperature, while the yield stress of the highest oxygen alloy, 4.18 at. pct., varied from 118,000 psi (fracture stress) at 77°K to 21,000 psi at 500°K. For intermediate oxygen contents and test temperatures, it was observed that the yield stress increased systematically with oxygen content at a given temperature. The data seem to indicate that at temperatures above about 550°K all alloys would exhibit the same flow stress, independent of oxygen content. This suggests that the barrier the oxygen atoms present to moving dislocations is easily overcome at 550°K and higher.

The measurements of the flow stress increments due to sudden increases in strain rate reflect the basic dislocation structure existing at the time of the strain rate change. The stress increments, $\Delta\sigma$, were found to increase rather rapidly with oxygen concentration at a given temperature. The magnitude of the effect can be seen from the fact that for pure zirconium $\Delta\sigma$ range from 350 to 750 psi (at the various testing temperatures), while the 4.18 at. pct. oxygen alloy exhibited values of $\Delta\sigma$ from 4,200 to 10,200 psi. There seems to be no systematic temperature dependence of $\Delta\sigma$ at a given oxygen concentration. Theoretically, the increase of $\Delta\sigma$ with oxygen indicates that the activation volume decreases with the amount of oxygen present. This suggests that either the dislocation density of the material is greatly increased by the presence of the oxygen atoms, or that the average pinning distance of the glide dislocations is reduced. The microstructural deformation modes have been surveyed. In the pure zirconium, deformation behavior was found to parallel closely earlier observations by other investigators, i.e., twinning on $[10\bar{1}2]$, $[11\bar{2}1]$, and $[11\bar{2}2]$ planes, with $[11\bar{2}1]$ planes predominating at low temperatures. Slip occurred primarily on $[10\bar{1}0]$ planes, and there was little evidence of any cross slip mechanism operating.

At an intermediate oxygen content (2.5 at. pct.), the behavior was markedly different from pure zirconium. Twins form on $[11\bar{2}1]$ planes, but much less frequently at lower temperatures, suggesting a more difficult nucleation mechanism. Also, the slip modes were rather drastically changed. Basal slip traces were frequently observed at all temperatures, but particularly in the lower range. In addition, these basal slip traces were almost always wavy, indicating a cross slip mechanism. In some cases the second slip plane was identifiable and proved to be a $[10\bar{1}1]$ plane, suggesting that the slip direction for $[10\bar{1}1]$ slip planes is a $\langle 11\bar{2}0\rangle$ direction.

At the highest oxygen content studied (4.18 at. pct.), brittle behavior was observed macroscopically at low temperatures. However, electron microscope observations of the fracture surfaces indicate that a ductile type of failure actually occurred. At least one crystal embracing the fracture showed rather strong evidence of cross slip on $[10\bar{1}0]$ - $[10\bar{1}1]$ planes. At the higher test temperatures where ductile behavior was observed, microscopic examination indicated that twins of the $[10\bar{1}2]$ type formed frequently. Wavy slip traces were again indicative of a cross slip mechanism, but the participating planes were of the $[10\bar{1}0]$ -$[10\bar{1}1]$ type as compared to $[10\bar{1}1]$ - (0002) at lower oxygen levels. Again, the evidence strongly suggests $\langle 1120\rangle$ as the slip direction for $[10\bar{1}1]$ pyramidal slip. In addition, at the highest test temperatures, $[11\bar{2}2]$ slip traces have been observed but no evidence of the slip direction for this mode has been obtained. Finally, at the highest temperature, some cracks were observed in one large grain, They apparently were nucleated in the matrix at an orientation nearly that of the basal plane, which happened to be nearly perpendicular to the stress axis, but were prevented from spreading by their intersection with $[10\bar{1}2]$ [illegible] existing in the grain.

5. Publications: No publications have yet resulted directly from this work. However, a doctoral dissertation is being based on this research, and it is anticipated that one or more significant papers will result.

6. Budget for period May 1 through November 1, 1965:

Salaries	$ 2,154.00
Expenses	939.38
Capital Equipment	2,350.53
TOTAL EXPENDITURES	$ 5,443.91

PROJECT A12

LOW TEMPERATURE INTERGRANULAR FRACTURE OF MAGNESIUM

1. Department: Metallurgical and Materials Engineering

2. Principal Investigator: Robert E. Reed-Hill

3. Background: The objective of this project is to analyze the mechanisms of low temperature deformation and fracture in polycrystalline magnesium. Since the early stages of this investigation, most work has been conducted on the room temperature plastic properties, as a number of unique and interesting phenomena occur in this temperature range. Of primary concern has been $[10\bar{1}1]$ - $[10\bar{1}2]$ second-order twinning. This double twinning mode, commonly referred to as $[30\bar{3}4]$ twinning, is of practical significance, since partings often are observed along these lamellae, and from these open up into grain boundary fractures. Also, these twins are capable of undergoing large plastic deformations, whereas, macroscopically speaking, polycrystalline magnesium is normally brittle at room temperature. Also of interest is the morphology of the $[30\bar{3}4]$ habit, which lies at an angle of 54° with the basal plane. This means that a habit shift of 8° occurs upon retwinning, since the primary [1011] twin habit lies at 62° to the basal plane. It is thought that knowledge of the mechanism here involved may lead to a better understanding of the irrational habits observed in martensite products.

4. Progress from May 1 to November 1, 1965: The orientation relationships associated with $[30\bar{3}4]$ twins are complex. For this reason, it was thought that the twin structures might be better understood if studied in single crystal specimens. Single crystal tensile specimens with the basal plane nearly parallel to the tensile axis were tested in an Instron tensile testing machine at a strain rate of .002 in./in./min. $[30\bar{3}4]$ twins were observed shortly after yielding, and specimens tested to failure exhibited a total elongation of less than one percent. All failures occurred along second-order twins. Observations were made on the $(11\bar{2}0)$ surface, since this is the plane of shear for $[10\bar{1}1]$ -$[10\bar{1}2]$ twinning.

Because of the small size of these twins and the high magnifications needed to resolve their internal structure, observations have been made on the electron microscope using the cellulose acetate-carbon double replica technique. These observations reveal that once a $[30\bar{3}4]$ twin forms, it deforms internally at a rapid rate. The shear in these regions, measured by the offset of basal slip lines, is often of the order of several hundred percent. It is difficult to account for this large deformation in terms of the normal, crystallographic slip modes, for the external surface of these deformed twins reveals wavy flow lines closely parallel to the twin habit. It appears from this that these narrow twins are concentrating a high shear stress along their length, with a resulting viscous behavior of the internal material.

It was found that the regions near the twin tips were relatively undeformed, and it was here that the actual twin structure could be studied. Observations reveal that the macroscopic twins are composed of small, individual lamellae of the order of 1μ thick and 5-10μ long. The habit of these individual lamellae lies at 50-52°, but they align in such a manner as to produce the macroscopically observed habit at 54°.

The mechanism involved in the twin habit shift is still not fully understood. An etching technique has recently been perfected which produces crystallographic grooves along the basal plane trace. This allows identification of matrix, primary, and secondary twin volumes in the electron microscope. In addition, a high density of matrix bend planes associated with the individual twin lamellae has been revealed. At present, a mechanism is being conceived which would account for the habit shift in terms of kinking in the primary twin and matrix in such a manner as to accomodate the doubly twinned volume.

5. Budget for Period May 1 to November 1, 1965:

Salaries	$ 2,092.80
Expense	271.70
Capital Equipment	1,500.00
TOTAL EXPENDITURES	$ 3,864.50

PROJECT A13

A STUDY OF FLUID (INCLUDING PLASMA) STATES OF MATTER

1. Department: Physics and Astronomy

2. Principal Investigators: A. A. Broyles and C. F. Hooper

3. Background: This program is developing methods of computing thermodynamic and other properties of fluids including plasmas. Specifically, we are concerned with the equation of state, the scattering intensities of x-rays and neutrons off of fluids, and the shape and width of spectral lines from hot plasmas. In addition to plasmas, we are considering liquid noble gases and liquid alkali metals. Our studies have started with classical systems, since they form the high temperature limit of quantum systems. Techniques developed for these systems have been extended to quantum mechanical systems by working down from high temperatures to low. We are also computing the properties of the ground state of liquid helium.

4. Progress from May 1 to November 1, 1965: We have continued our calculations of pair potentials from liquid krypton scattering data for neutrons at various temperatures and densities. This work is still in progress.

An IBM 709 program is being constructed to obtain the ground state wave function for liquid helium. It solves the equation obtained by Kiroike by minimizing the energy, using a trial wave function in the form of a Boltzmann factor with effective pair potentials. This equation involves the assumption that the bridge diagrams in the Mayer cluster expansion for the radial distribution function can be neglected. We are developing means for avoiding this last approximation, which is known to be poor in certain applications of interest.

We have obtained effective pair potentials for ideal Bose and Fermi gases that, when included in a classical Boltzmann factor, give a good approximation to the Slater Sum. In the case of the Fermi gas, we have covered the range from absolute zero to infinite temperature. The energies computed from these effective potentials are in error by, at worst, 8%; over most of the range the error is much smaller than this. Effective potentials for the quantum, non-ideal electron gas at high temperatures and high densities have also been obtained to give approximate Slater Sums. This work is continuing and the methods are being improved.

Calculation of the radial distribution function for the classical electron gas has been completed for the temperature parameter 0 down to 0.4, and a paper covering this work has been approved for publication in the Journal of Chemical Physics.

Our work on the calculation of electric microfields in plasma has progressed to the point where final results are being collated and evaluated. Preliminary results indicate that the formalism and calculational technique that we have developed is considerably more efficient than other previous approaches, in that it is valid for a much wider range of temperature-density parameters. The method is also more flexible, since it can readily be adapted to strictly quantum mechanical plasmas with the aid of effective potentials.

5. Publications:

A. A. Broyles and A. A. Kahn. "Interatomic Potential of Krypton", American Physical Society, Washington Meeting, April 26-29, 1965. Bull. Am. Phys. Soc. 10, 458 (1965).

A. A. Kahn and A. A. Broyles. "Interatomic Potentials and X-ray Diffraction Intensities for Liquid Xenon", J. Chem. Phys. 43, 43(1965).

A. A. Kahn and A. A. Broyles. "Effecitve Interatomic Potentials for Liquid Helium Above and Below the λ Point", Phys. Rev. 139 A1805 (1965).

D. D. Carley. "Recent Studies of the Classical Electron Gas", J. Chem. Phys. (in press).

6. Budget for period May 1 to November 1, 1965:

Salaries	$ 5,781.68
Expenses including computing	9,246.50
TOTAL EXPENDITURES	$15,028.18

PROJECT A15

MOLECULAR BEAM INVESTIGATIONS OF SURFACE REACTIONS

1. Department: Chemistry

2. Principal Investigator: E. E. Muschlitz, Jr.

3. Background: In recent years, molecular beams have been used with considerable success in basic kinetic studies of gas phase reactions. The molecular beam technique has a number of distinct advantages when applied to the problem of surface reactions. The surface under investigation may be oriented with respect to the direction of the incident molecules, the angular distribution of the particles leaving a hot surface may be studied, and the identity of any active species produced (excited molecules, atoms, or free radicals) may be determined before they are destroyed by gas phase or wall collisions. Very few studies along these lines have so far been attempted. Yet the information which may be obtained is of considerable value with respect to a number of practical problems arising in the space program, particularly in the problem of re-entry. The method is capable of yielding direct information regarding such surface properties as catalysis, residence time, and accommodation efficiency.

4. Progress from May 1 to November 1, 1965: The apparatus for this research has been constructed inside a large vacuum chamber approximately four feet in diameter and two feet high. The surface to be investigated is mounted, in the form of a ribbon, in the center of this chamber and heated electrically to temperatures in the range 1000-2500°K. A molecular beam source is now under construction. Molecules and radicals leaving the surface will be identified using an Electronics Associates Inc. four-pole mass spectrometer. The mass spectrometer has been mounted so that it can be rotated about the surface, utilizing a gear and chain drive coupled to a rotatable shaft extending through a vacuum seal in the chamber wall. Thus, studies may be made of the formation of radicals as a function of angle of incidence of the molecular beam, the angle at which they leave the surface, and the temperature of the surface.

Construction of the apparatus, with the exception of the molecular beam source, is complete, and construction of the source has now been started. It is planned to incorporate in the source a glass capillary array, a new development in the production of high intensity molecular beams. The vacuum chamber and pumping system have been thoroughly checked, and a background pressure of 3×10^{-7} torr is routinely achieved. Preliminary experiments using the mass spectrometer to identify the residual gas at this pressure have also been made. The ion intensities observed were such that no difficulties are expected in detecting and identifying the particles leaving the hot surface in the experiments planned, provided the incident molecular beam is chopped and a phase sensitive amplifier is used in the detector circuit.

Prior studies by Smith and Fite have shown that when a beam of hydrogen molecules is incident on a hot tungsten surface the resulting hydrogen

atoms come off with a cosine distribution. It is planned to reinvestigate this system and to extend the measurements to D_2 and HD. In the case of HD molecules incident on the surface, it will be very interesting to obtain the relative production of H_2 and D_2 as a function of angle. In order to distinguish between D^+ and H_2^+ it will be necessary to make measurements both above and below the appearance potential of D^+. The measurements will eventually be extended to oxygen and to nitrous and nitric oxides as well.

5. Publications: No publications have resulted as yet from this research. It is hoped that the preliminary results to be obtained with H_2 and D_2 will be presented at a scientific meeting next spring.

6. Budget for Period May 1 to November 1, 1965:

Salaries	$6,389.00
Expenses	2,083.00
Capital Equipment	1,494.00
TOTAL EXPENDITURES	$9,966.00

PROJECT A16

EXPERIMENTAL STUDIES OF ELECTRONIC AND IONIC COLLISIONS

1. Department: Physics and Astronomy

2. Principal Investigators: T. L. Bailey and B. S. Thomas

3. Background: The research of this project consists of several types of electron and ion collision experiments, all of which are closely connected with space physics. More specifically, these are: (a) studies of the energetics and dynamics of ion-molecule reactions, of the general type $A^+ + BC = AB^+ + C$, and of collision-induced dissociation, such as $D_2^+ + Ar = D^+ + D + Ar$; and (b) studies of collisions of electrons with molecular ions. The rather complex apparatus to be used for both the ion and electron collision experiments is complete, and extensive studies of ion-neutral collisions have been carried out. This research receives concurrent support from an Air Force Office of Scientific Research Grant.

4. Progress from May 1 to November 1, 1965: Studies of the collision-induced dissociation reaction, $D_2^+ + X = D^+ + D + X$, where the target X is He, Ar, O_2, or N_2 have been carried out with D_2^+ ion laboratory energies in the range $20 < E_1 < 100$ eV. The experimental method is to direct a well-collimated, mass analyzed, velocity selected beam of D_2^+ ions into a region containing a target gas of X atoms or molecules at low density. The D^+ ions arising from dissociation, which emerge from the target region at a given scattering angle, are then velocity selected, identified by mass analysis, and finally detected by means of an electron multiplier. The experimental arrangement thus gives kinetic energy distributions of D^+ products, at any selected scattering angle, and also angular distributions of the product ions. The observed product D^+ ion energy distributions exhibit two interesting features: (1) a sharp peak, centered at D^+ energy equal to $(E_1/2 - 0.28)$eV; and (2) a diffuse, lower intensity distribution, centered about the sharp peak. The position of the maximum in the sharp peak (given by the preceding expression) was found to be the same over the entire range of primary ion energies E_1, and also independent of the target gas, within experimental error. Studies of the angular dependence of the product D^+ ions has shown that those ions contributing to the sharp kinetic energy peak are very strongly forward collimated, while those contributing to the diffuse peak are more broadly distributed in angle. These results are most interesting, and we are at present attempting to explain them in terms of various collision models. Although the explanations are far from complete, it is clear that the dissociation process cannot be regarded as a vertically-upward excitation of D_2^+ to the repulsive state, $D_2^+ + X = (D_2^+)^* + X$, followed by decomposition of the excited $(D_2^+)^*$, $(D_2^+)^* = D^+ + D$. The D^+ kinetic energy distributions predicted by this two-step model are quite different from those actually observed. The existence of both sharp and diffuse peaks in the energy distributions also suggests that there are two distinct mechanisms for the reactions.

Angular and energetic studies of the following ion-molecule reactions are in progress:

(i) $D_2^+ + H_2 = D_2H^+ + H$

(ii) $N_2^+ + D_2 = N_2D^+ + D$

(iii) $Ar^+ + D_2 = ArD^+ + D$

These experiments are not yet complete, but several interesting features are already apparent. In each case, the reactions seem to be proceeding by a "pickup" mechanism, in which the product ion leaves the collision region with essentially the same linear momentum as the incident primary ion. In the case of reaction (iii), the ArD^+ product kinetic energy distributions, at a fixed scattering angle, show pronounced structure which is believed to arise from vibrational excitations of the ArD^+ molecule. With further refinement of the experimental method it should be possible to measure the vibrational level spacings of ArD^+, and other molecules, with considerable accuracy. From its success thus far, it is believed that the present experiment is a potentially powerful tool for studies of molecular structure, as well as of the dynamics of reactive collisions.

5. Publications:

T. L. Bailey, R. L. Champion, L. D. Doverspike, and J. J. Leventhal. "Angular and Energetic Studies of Reactive Ion-Neutral Collisions." Paper presented at IVth International Conference on the Physics of Electronic and Atomic Collisions, Quebec, August, 1965.

J. J. Leventhal. Energetic and Angular Studies of D_2H^+ Formation in $D_2^+ - H_2$ Collisions, Ph.D. dissertation, University of Florida, August, 1965.

R. L. Champion, T. L. Bailey, and L. D. Doverspike. "Collision Induced Dissociation of D_2^+ in Various Gases," Paper presented at S.E. Section Meeting, Am. Phys. Soc., Charlottesville, Virginia, November, 1965.

6. Budget for Period May 1 to November 1, 1965:

Salaries	$ 775.00
Expenses	2858.42
Capital Equipment	2224.03
TOTAL EXPENDITURES	$5857.45

PROJECT A17

NUCLEAR PROPULSION PROBLEMS

1. Department: Nuclear Engineering

2. Principal Investigator: Robert E. Uhrig

3. Background: This investigation is concerned with some of the peculiar problems associated with operation of nuclear reactors in space as a primary source of power for propulsion and electrical power.

4. Progress from May 1 to November 1, 1965:

MODEL REFERENCE ADAPTIVE CONTROL SYSTEM

Work has continued in applying model reference adaptive techniques to control of a nuclear rocket engine. As the name implies, the model reference control system employs a model which embodies the design specifications for the system to be controlled. A command input is applied simultaneously to the reference model as well as to the basic control loop. The system output is compared with the reference model output, and a signal representing the error between actual and desired performance is made available. Requirement for parameter adjustment is determined by generating functions of the error, and parameter-variation commands are sent to parameter adjustment devices in the control system. Thus the controller "adapts" or changes in such a manner that the system output closely matches that of the model.

Adaptive control techniques are particularly well suited for systems with dynamics that are not thoroughly understood, and with characteristics that may be dependent upon environmental conditions. Nuclear rocket engines may belong in this category of systems, hence the need for this control systems study.

Computer simulation is essential for design and analysis, since the problem is too difficult for conventional analysis. The computer being used in this research is the Applied Dynamics AD-80 general purpose analog computer, which is housed in the Department of Nuclear Engineering. During this report period, a nuclear rocket engine complete with conventional feedback control system has been simulated. To this has been added an adaptive loop containing the reference model and the parameter adjustment mechanisms. More than 80% of the computer's operational amplifiers are being used in this simulation. Some measure of self-adaptivity has been noted, and preliminary results are encouraging.

At present, close attention is being given to design of the reference model. Computer simulation indicates that a second order model with a zero in its transfer function best represents the desired performance of the nuclear rocket engine.

In the near future, response of the nuclear rocket engine will be observed as certain engine characteristics are varied. This will be first performed

under conventional feedback control, and then under model reference adaptive control. Performances of the two control systems will be compared to determine the advantages, if any, which accrue from application of the model reference technique.

NEUTRON FLUX STATE OPTIMIZATION VIA THE MAXIMUM PRINCIPLE OF PONTRYAGIN

Problem Description

Given $\dot{x}_i = f_i(x_1, x_2, u, t) \qquad i = 1, 2$ (1)

where $x_1 \equiv n$, $x_2 \equiv c$ and u is the control variable.

Construct a Hamiltonian

$$H(x,u,p,t) = \sum_{i=1}^{2} P_i(t)\, \dot{x}_i(x_1, x_2, u, t) \tag{2}$$

where P(t) is the auxiliary vector.

Auxiliary functions are now defined as:

$$\dot{P}_i(t) = \frac{-\partial H(x,u,p,t)}{\partial x_i} \tag{3}$$

The problem at hand is, given N(t=0) and c(t=0), to obtain the response for n such that $n(T) = an_o$ and $\dot{n}(T) = 0$, satisfying the performance criteria

$$J = \int_0^T u^2\, dt. \tag{4}$$

In the previous report it was mentioned that the above boundary conditions at the final time were satisfied by varying the initial conditions on the auxiliary functions. Since the last report, a logic system has been developed to exploit the hybrid capabilities of the AD-80 analog computer so as to arrive at similar results by an iterative procedure.

The updating equations used for the iterative procedure are:

$$P_1^{j+1} = P_1^{j}(0) \pm K_{11}\left[n^j(T) - n(T)\right] \pm K_{12}\left[\dot{n}^j(T) - \dot{n}(T)\right] \tag{5}$$

$$P_2^{j+1} = P_2^{j}(0) \pm K_{21}\left[n^j(T) - n(T)\right] \pm K_{22}\left[\dot{n}^j(T) - \dot{n}(T)\right] \tag{6}$$

The values obtained from the time response of the auxiliary functions at t = T have also been used to solve the system equations optimally by the numerical technique of quasilinearization on the IBM-709 computer. The results are in close agreement. This problem is being applied to a nuclear rocket reactor system with temperature feedback and hydrogen density coefficient of reactivity.

5. Publications: None to date; three dissertations underway.

6. Budget for Period May 1 to November 1, 1965:

Equipment	$20,890.00

PROJECT A19

PHOTOELECTRIC PHOTOMETRY IN THE STUDY OF ECLIPSING VARIABLE STARS

1. Department: Physics and Astronomy

2. Principal Investigator: Kwan-Yu Chen

3. Background: A program for the study of eclipsing variable stars was begun in the fall of 1964. The observatory, which is located at Gainesville, Florida, contains a 12.5-inch Newtonian reflector with a photoelectric photometer head, a DC amplifier, power supplies, and a strip-chart recorder. The study consists mainly of four parts:

(1) Determination of atmospheric extinction coefficients
(2) Observations of selected eclipsing variables
(3) Reduction and analysis of the observed data
(4) Improvement of theories regarding to the physical nature of these stellar systems.

4. Progress from May 1 to November 1, 1965: In determining atmospheric extinction coefficients, R. B. Carr, a graduate student, made observations on beta Pegasi, delta and epsilon Andromedae, alpha and gamma Trianguli, and 35 Arietis in three colors (UBV). The spectral types of these stars range from M0 to B3. A computer program was written to set up tables of hour angle and the secant of zenith distance for six stars of given declinations. The range of hour angles in these tables is from zero to seven hours, with an increment of one minute. The values of these tables were obtained from the IBM 709 located at the University Computer Center.

A second graduate student, F. A. Herrero, is doing a theoretical study of the reflection effect in eclipsing variables. In his study, the shape of the stars is considered to be spherical and the stars are considered to radiate as black-bodies. Both Mr. Carr and Mr. Herrero were one-third-time research assistants on this project during the period of the report.

K-Y Chen is continuing the work of photoelectric photometry of selected eclipsing variables. One of the stars observed is BV 623. Observation of SX Cassiopeiae is also being continued. The University has now received from the National Science Foundation a Science Development Grant of $4.2 million, including funds for a telescope of approximately 30 inches aperture. A study of available instruments is underway and it is hoped that the contract may be let soon. When available, the newer and larger telescope will add greatly to the work of this project.

5. Publications: A paper entitled "Photoelectric Photometry of 44i Bootis," was presented at the Thirty-second Meeting of the Southeastern Section of the American Physical Society by K-Y Chen and D. A. Rekenthaler.

6. Budget for Period May 1 to November 1, 1965:

Salaries	$4633.10
Expense	401.14
TOTAL EXPENDITURES	$5034.24

PROJECT A20

A THEORETICAL AND EXPERIMENTAL INVESTIGATION OF OPTIMUM EXPERIMENTAL CONDITIONS FOR ANALYSIS OF ATOMS BY ATOMIC EMISSION AND ATOMIC ABSORPTION FLAME SPECTROMETRY

1. Department: Chemistry

2. Principal Investigator: J. D. Winefordner

3. Background: Atomic emission and atomic absorption flame spectrometry are two of the most accurate, rapid and sensitive methods available for quanitative analysis of metals. The selection of optimum experimental conditions for analysis has up to now involved a nearly completely empirical approach; i.e., optimum experimental conditions are normally determined by a trial and error process which is not only time consuming but often is highly inaccurate. This project is therefore concerned with a systematic, theoretical approach to the selection of optimum experimental conditions for the measurement of any element by an experimental system using atomic emission and atomic absorption flame spectrometry. By the choice of optimum experimental conditions, the greatest signal-to-noise ratio will result, and therefore the greatest sensitivity and accuracy of measurement.

4. Progress from May 1 to November 1, 1965: During this period, a Fortran program was written to allow calculation of the approximate total half-intensity line widths of several lines for a number of atoms in some common analytical flames. By means of this program, total half-intensity line widths of any atomic spectral line can be calculated if sufficient spectral and flame compositional data are available. Calculations of total half-intensity line widths of lines of sixty elements in five different flame types have been made and the data have been tabulated. The total half-intensity line width, $\Delta\lambda_T$, in Angstroms, is related to the Doppler half-intensity line width, $\Delta\lambda_D$, the natural half-intensity line width, $\Delta\lambda_N$, the resonance half-intensity line width, $\Delta\lambda_R$, and the collisional half-intensity line width, $\Delta\lambda_C$, by

$$\Delta\lambda_T = [(\Delta\lambda_D)^2 + (\Delta\lambda_C + \Delta\lambda_R + \Delta\lambda_N)^2]^{1/2}$$

The values of $\Delta\lambda_T$ were found by evaluating $\Delta\lambda_D$, $\Delta\lambda_C$, $\Delta\lambda_R$ and $\Delta\lambda_N$ for various lines of sixty elements in five different flames. The importance of this study is as follows. In atomic absorption flame spectrometry, it is necessary to use a spectral source with a line width narrower than the half-intensity width of the absorption line width of the atom being studied to prevent loss of sensitivity and deviation from linearity in the analytical curve. When using wide line sources or continuous sources for atomic absorption flame spectrometry, the spectral band width of the monochromator and the half-intensity width of the absorption line must be known in order to estimate the decrease in sensitivity of analysis as compared to an infinitely narrow emission line from the source. Therefore, in atomic absorption measurements, a knowledge of the half-intensity absorption line widths is of considerable analytical importance in the choice of spectral lines, in the design of instrumentation and in the prediction of shapes of analytical curves. In atomic emission flame spectrometry, the width of the

emission lines is important in theoretical studies such as estimation of the total absorption or the integrated intensity of a spectral line. A knowledge of half-intensity line widths, however, is certainly of less practical value in atomic emission flame spectrometry than in atomic absorption studies. In the new analytical method of atomic fluorescence flame spectrometry, a knowledge of absorption line widths of atoms in flames, as well as source line widths, is needed in order to choose properly the optimum spectral lines for study, to decide on the best experimental system and to predict the influence of experimental conditions and the limit of detectability.

Other studies initiated during the above period include the following. An experimental study is being carried out involving the measurement of collisional half-intensity line widths, $\Delta\lambda_C$, collisional cross-sections, σ_C, and damping constants, a, for various spectral lines of a number of atoms. The damping constant, a, is defined by

$$a = \frac{\Delta\lambda_N + \Delta\lambda_R + \Delta\lambda_C}{\Delta\lambda_D} \sqrt{\ln 2} .$$

In order to estimate total half-intensity widths of spectral lines, it is necessary to know $\Delta\lambda_C$. The importance of such measurements is mentioned in the above paragraph. An experimental study involving long absorption path lengths for atomic absorption flame spectrometric studies is also being carried out. In this problem, the flame is extended in length by allowing the flame gases to extend down a quartz tube. This results in an increased residence time of any given atom in the absorption path, which results in increased sensitivity of analysis. By means of such studies, it should be possible to determine elements in concentrations as low as 10^{-9} grams per milliliter of solution. The need for highly sensitive, accurate methods for trace analysis of elements in a variety of samples is certainly great.

5. Publications:

M. L. Parsons, W. J. McCarthy, J. D. Winefordner. "Approximate Half-Intensity Widths of a Number of Atomic Spectral Lines Used in Atomic Emission and Atomic Absorption Flame Spectrometry," submitted to Applied Spectroscopy Journal.

6. Budget for Period May 1 to November 1, 1965:

Salaries	$2,400.00
Expense	123.57
Capital Equipment	1,241.20
TOTAL EXPENDITURES	$3,764.77

PROJECT A21

NUCLEON-NUCLEON FORCE

1. Department: Physics and Astronomy

2. Principal Investigator: A. E. S. Green

3. Progress in the Period May 1 to November 1, 1965: The work accomplished to date under A21 has been highly rewarding, especially considering the very modest nature of the expenditures ($1500). We have established the fact that the theoretical work on meson theory of nuclear forces carried out by the senior investigator in 1949 contains the same pseudoscalar, vector and scalar mesons utilized by several groups during the past year. Inserting recently-discovered meson masses into our old theoretical expressions, we have derived a set of nucleon-nucleon potentials which agree favorably with phenomenological nucleon-nucleon potentials recently inferred from nucleon-nucleon data. Our work (see March 8 Phys. Rev. Letters) differed in two respects from the recent work of Bryan and Scott: (1) They did not have velocity dependent terms in their central potentials; (2) they utilized a 500 MeV scalar meson, whereas we use a meson comparable in mass to the ω meson (i.e. $\sim$ 700 MeV.). The former difference has been resolved, in that they have now found the missing velocity dependent terms, which agree identically with our own. Recent experimental evidence on the existence of a scalar meson is now favoring the 700 MeV value required in our theory.

The Office of Scientific Research has recently awarded a substantial grant for the continuation and development of this theoretical program. Hence we will require no further support from the NASA Institutional Grant for this research. We hope that the "seed corn" provided by the Institutional Grant will blossom and yield a rich harvest in fundamental knowledge.

4. Publications:

A. E. S. Green and R. D. Sharma. "Velocity-Dependent Nucleon-Nucleon Interaction," Bull. Amer. Phys. Soc. 10, 71 (1965).

A. E. S. Green and R. D. Sharma. "Mesonic Nucleon-Nucleon Potentials," Bull. Amer. Phys. Soc. 10. 448 (1965).

5. Budget for period May 1 to November 1, 1965:

Salaries	$ -0-
Expenses	350.00
Capital Equipment	-0-
TOTAL EXPENDITURES	$ 350.00

PROJECT A22

HYDROTHERMODYNAMICS OF A PLANE LAMINAR JET

1. Department: Aerospace Engineering

2. Principal Investigator: Knox Millsaps

3. Background: One of the classical situations in fluid dynamics is the laminar flow of a fluid through an opening into the same fluid, which has no secondary motion; or, to be more precise, an analytical description of the flow resulting from the continuous application of a force either at a point or along a line in a fluid medium. It is traditional to refer to the two different situations, respectively, as the "round" and "plane" jet.

First, for the case of the plane jet, Schlichting reduced the boundary layer equations to an ordinary differential equation, which he then treated by continuous joining of a power series from the origin with an asymptotic expansion; unfortunately, Schlichting also made numerical errors. Bickley, in a truly remarkable paper, then showed that the involved treatment by Schlichting was unnecessary by exhibiting a closed form solution to the ordinary differential equation in terms of hyperbolic functions. Yih used Bickley's solution to treat with a similarity transformation the associated heat transfer problem, in which the usual thermal boundary layer assumptions are made and in which all effects due to viscous dissipation are neglected. The attempted experimental verification of the hydrodynamics by Andrade yielded only "tolerably good results," and in view of the philosophical stakes it seemed that another attempt at an admittedly difficult experiment would be worthwhile. As far as is known, reliable data on the heat transfer problem do not exist.

For the round jet, Landau has given an exact solution, in closed form, to the complete Navier-Stokes equations for the hydrodynamic problem; and Squire has given a closed form solution to an approximate energy equation for the associated heat transfer problem. Unfortunately, Squire's solution for the thermal distribution in a round jet can be criticized on exactly the same ground as the solution by Yih for the plane jet. On one hand, an exact solution for Squire's problem would seem to be more interesting, in that the hydrodynamic solution is an exact solution of the Navier-Stokes equations, whereas the plane jet has been solved only with the boundary layer hypothesis; on the other hand, the plane jet may be the more interesting example because of the wider applicability of boundary layer theory.

In a frequently-quoted paper, Andrade and Tsien have reported on an experimental determination of the velocity distributions in a round jet made by photographing the paths of aluminum particles during measured intervals. Their comparison of the results of theoretical analysis and experimental data was based on calculations by Schlichting, who used boundary layer assumptions.

4. Progress from May 1 to November 1, 1965: Mr. D. C. Daniel has recently tried to improve the experimental data of Andrade for the hydrodynamics of

a plane laminar imcompressible jet; unfortunately, because of mechanical vibrations and a poor space-time differentiation technique, Daniel's data are not substantial improvements on the previous attempt by Andrade. The experiment will have to be repeated with much greater care and attention to detail.

Millsaps and Soong completed in October of 1965 an exact treatment of the thermal boundary problem which had been treated previously by Yih by a physically unacceptable approximation. The completed manuscript has been sent to an international technical journal.

Experimental data on the heat transfer problem have not been obtained because of the failure to realize the hydrodynamic experiment; however, the fabrication and calibration of the microthermocouples have been continued by Mr. A. J. Evans by studying the thermal fields in Benard cells.

5. Publications:

D. C. Daniel. The Laboratory Production of a Stable Plane Laminar Jet, Master's Thesis, University of Florida, August, 1965.

6. Budget for Period May 1 to November 1, 1965:

Salaries	$3,213.10
Expenses	506.84
Capital Equipment	251.41
TOTAL EXPENDITURES	$3,971.35

LIST OF PUBLICATIONS SUBMITTED TO NASA DURING THE REPORT PERIOD

Project A01

"Influence of the Terrestrial Environment on the Temporal and Statistical Characteristics of Jovian Decametric Radiation." Alex G. Smith, W. F. Block, W. A. Morton, G. R. Lebo, and T. D. Carr. Presented at the 2nd Symposium on Radio Astronomical and Satellite Studies of the Atmosphere, Cambridge, Massachusetts. October 19-21, 1965. (Preprint: complete text to be published in the proceedings.)

"Tests for Local Modulation of Jovian Decametric Emission." Alex G. Smith, W. F. Block, G. R. Lebo, and W. A. Morton. Presented at the annual meeting of the Southeastern Section of the American Physical Society, University of Virginia. November 1-3, 1965. (Preprint of abstract.)

Project A02

"Observations with the 1000-Foot Arecibo Radio Telescope." Thomas D. Carr and C. Frank Tiberi. Presented at the annual meeting of the Southeastern Section of the American Physical Society, University of Virginia. November 1-3, 1965. (Preprint of abstract.)

"Polarization of the Radiation from Jupiter at Low Frequencies." D. J. Kennedy, Thomas D. Carr, and Alex G. Smith. Presented at the annual meeting of the Southeastern Section of the American Physical Society, University of Virginia. November 1-3, 1965. (Preprint of abstract.)

"Asymmetrical Stop Zones in Jupiter's Exosphere." Samuel Gulkis and Thomas D. Carr. (Preprint: submitted to Nature.)

"Results of Recent Investigations of Jupiter's Decametric Radiation." T. D. Carr, S. Gulkis, A. G. Smith, J. May, G. R. Lebo, D. J. Kennedy, and H. Bollhagen. Radio Science, December, 1965. (Portions of this work were derived from A03.)

Project A03

"Correlation of the Longitudes of the Galilean Satellites with Jupiter's Decametric Radiation." G. R. Lebo, A. G. Smith, and T. D. Carr. Presented at the American Astronomical Society meeting, Lexington, Kentucky. March 14-17, 1965. (Reprint of abstract.)

"Jovian Rotation Periods and the Origin of the Decametric Burst Structure." Alex G. Smith, G. R. Lebo, C. N. Olsson, W. F. Block, N. F. Six, and T. D. Carr. Invited contribution presented at the CALTECH-JPL Lunar and Planetary Conference. September 13-18, 1965. (Preprint: to be published in full in the Proceedings of the Conference.) (Portions of this work were derived from Project A01.)

Project A03 (continued)

"The Effect of Io on Jovian Decametric Radio Emission." G. R. Lebo, T. A. Anderson, A. G. Smith. Presented at the annual meeting of the Southeastern Section of the American Physical Society, University of Virginia. November 1-3, 1965. (Preprint of abstract.)

"Jovian Rotation Periods." C. N. Olsson, Alex G. Smith, and G. R. Lebo. Presented at the annual meeting of the Southeastern Section of the American Physical Society, University of Virginia. November 1-3, 1965. (Preprint of abstract.)

Project A06

"Probe Measurements in an Electrodeless Discharge." D. R. Keefer, M. H. Clarkson, and B. E. Mathews. To be presented at the Plasma Conference, American Institute of Aeronautics and Astronautics, Monterey, California. March 2-4, 1966. (Preprint)

Project A07

"Two Simple Turbulent Flows." W. N. DeCarlis, R. L. Fearn, and Knox Millsaps. Journal of Geophysical Research 70, 2273-2274, 1965.

Project A08

"A Large Deflection Theory of Inflatable Shallow Shells." F. H. Ho and W. A. Nash. (Abstract of paper to be submitted to the Journal of the American Institute of Aeronautics and Astronautics.)

"Nonlinear Free Transverse Vibrations of Inflatable Shallow Shells." F.H. Ho and W. A. Nash. (Abstract of paper to be submitted to the Journal of the American Institute of Aeronautics and Astronautics.)

Project A13

"Effective Interatomic Potentials for Liquid Helium above and below the λ Point." Ashfaq A. Khan and A. A. Broyles. Physical Review, 139, A1805-A1806, 1965.

"Radial Distribution Functions of Liquid Krypton." Ashfaq A. Khan. Physical Review 136, A1260-A1279, 1964.

"Approximate Methods for Obtaining Radial Distribution Functions of Fluids." D. D. Carley and F. Ledo. Physical Review 137, A42-A50, 1965.

"Interatomic Potentials and X-Ray-Diffraction Intensities of Liquid Xenon." Ashfaq A. Khan and A. A. Broyles. Journal of Chemical Physics 43, 43-48, 1965.

"Recent Studies of the Classical Electron Gas." D. D. Carley. (Accepted for publication in the Journal of Chemical Physics.)

Project A16

"Collision Induced Dissociation of D_2^+ Ions in Various Gases." R. L. Champion, T. L. Bailey and L. D. Doverspike. Presented at Southeastern Section, American Physical Society Meeting, University of Virginia. November 1-3, 1965.

"Angular and Energetic Studies of Reactive Ion-Neutral Collisions." T. L. Bailey, R. L. Champion, L. D. Doverspike, and J. J. Leventhal. Presented at the IVth International Conference on the Physics of Electronic and Atomic Collisions, Quebec. August, 1965.

Project A19

"Photoelectric Photometry of 44i Bootis." K-Y Chen and D. A. Rekenthaler. Presented at the annual meeting of the Southeastern Section of the American Physical Society, University of Virginia. November 1-3, 1965. (Preprint of abstract.)

Project A21

"Velocity-Dependent Nucleon-Nucleon Interaction." A. E. S. Green and R. D. Sharma. American Physical Society, New York Meeting, January 27-28, 1965. Bull. Amer. Phys. Soc. 10, 71 (1965).

"Mesonic Nucleon-Nucleon Potentials." A. E. S. Green and R. D. Sharma. American Physical Society, Washington. April 26-29, 1965. Bull. Amer. Phys. Soc. 10, 448 (1965).

"Velocity-Dependent Nucleon-Nucleon Potentials." A. E. S. Green and R. D. Sharma. Physical Review Letters 14, 380-383, 1965.